QUALITY-ASSURANCE PLAN FOR SURFACE-WATER ACTIVITIES

IN THE ARKANSAS WATER

SCIENCE CENTER

Revision By: Bill Baldwin 08/12/2010

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Abstract

This U.S. Geological Survey Arkansas Water Science Center Surface-Water Quality-Assurance Plan documents the standards, policies, and procedures used by the Arkansas Water Science Center for activities related to the collection, processing, storage, analysis, and publication of surface-water data.

Introduction

The U.S. Geological Survey (USGS) was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to perform the systematic and scientific "classification of the public lands, and examination of the geologic structure, mineral resources, and products of the national domain." Surface-water activities in the Arkansas Water Science Center (ARWSC) are part of the Water Resources Division's (WRD) overall mission of appraising the Nation's water resources. Surface-water information, including streamflow, stage, and sediment data, is used at the Federal, State, and local levels for resources planning and management.

The purpose of the ARWSC Surface-Water Quality-Assurance Plan (QA Plan) is to document the standards, policies, and procedures used by the ARWSC for activities related to the collection, processing, storage, analysis, and publication of surface-water data.

This plan identifies responsibilities for ensuring that stated policies and procedures are carried out. The plan also serves as a guide for all ARWSC personnel involved in surface-water activities and as a resource for identifying memorandums, publications, and other literature that describe in more detail associated techniques and requirements.

The scope of this report includes discussions of the policies and procedures followed by the ARWSC for the collection, processing, analysis, storage, and publication of surface-water data. Specific types of surface-water data include stage, streamflow, sediment, and basin characteristics. In addition, issues related to the management of the computer database and employee safety and training are presented. Although procedures and products of interpretive projects are subject to the criteria presented in this report, specific interpretive projects are required to have a separate and complete QA plan.

This QA Plan is reviewed and revised at least once every 3 years in order that responsibilities and methodologies are kept current and in order that the ongoing procedural improvements can be effectively documented.

Responsibilities

Quality assurance is an active process. Achieving and maintaining high-quality standards for surface-water data are accomplished by specific actions carried out by specific persons. Errors and deficiencies can result when individuals fail to carry out their responsibilities. Clear and specific statements of responsibilities promote an understanding of each person's duties in the overall process of assuring surface-water data quality.

The following is a list of the positions and responsibilities of ARWSC personnel involved in the collection, processing, storage, analysis, or publication of surface-water data.

Director

John Terry

Data Chief

Jaysson Funkhouser

Studies Chief

David Freiwald

Field Office Chief

Little Rock Bill Baldwin

Fayetteville Kevin Hubbs

Hydrologic Technician

See Flood Plan (link below)

Computer/DBA

Brian Clark/Troy "Bubba" Brossett/Bill Baldwin

Safety Officer

Jeanne DeLanois

SW Specialist

Jaysson Funkhouser

The Director is responsible for;

1. Managing and directing the ARWSC program, including all surface-water activities.

2. Ensuring that surface-water activities in the ARWSC meet the needs of the Federal Government, the ARWSC, State and local agencies, other cooperating agencies, and the general public.

3. Ensuring that all aspects of this QA Plan are understood and followed by ARWSC personnel. This is accomplished by delegation of this responsibility to the Chief of the Hydrologic Records & Information Section.

4. Providing final resolution of any conflicts or disputes related to surface-water activities within the ARWSC.

5. Keeping subordinates briefed on procedural and technical communications from Regional Offices and Headquarters.

6. Performing technical reviews of all surface-water programs on a semiannual basis.

7. Ensuring that all publications and other technical communications released by the ARWSC are accurate and are in accord with USGS policy.

The Data Chief (Hydrologic Surveillance and Analysis Program) is responsible for;

1. Managing and directing the surface-water data programs in the ARWSC.

2. Ensuring that all aspects of this QA plan are understood and followed by ARWSC personnel.

3. Providing guidance and approval of on site selection, design, installation, and operation of all surface-water gaging stations in the ARWSC.

4. Performing technical reviews of all surface-water data programs.

5. Acting as Assistant Flood Coordinator during floods and ensuring that the flood plan is followed.

6. Coordinating compilation of data report and ensuring its accuracy.

7. Maintaining all surface-water databases.

8. Keeping subordinates briefed on procedural and technical communications.

9. Providing resolution of conflicts or disputes related to surface-water data collection activities.

10. Providing appropriate training and overseeing the safety program for subordinates.

The Studies Section Chief is responsible for;

1. Managing and directing the Hydrologic Studies program, including studies with surface-water components.

2. Ensuring that the surface-water interpretive studies in the ARWSC meet the needs of the Federal Government, the ARWSC, State and local agencies, other cooperating agencies and the general public.

3. Ensuring that all aspects of this QA Plan are understood and followed by Studies Section personnel. This is accomplished by the Studies Section Chief's direct involvement or through clearly stated delegation of this responsibility to other personnel in the Studies Section.

4. Providing training, management, and distribution of responsibilities within the Studies Section for all activities related to surface-water interpretive studies.

5. Keeping staff members briefed on procedural and technical communications from the ARWSC, Regional Offices and Headquarters.

6. Ensuring that all Studies Section projects have written QA Plans and that technical communications released by the Studies Section are accurate and are in accord with USGS policy.

7. Performing regular technical reviews of Studies Section projects.

The Field Office Chief (Little Rock/Fayetteville) is responsible for;

1. Managing and directing the surface-water data program assigned to the field office.

2. Ensuring that all aspects of this QA plan are understood and followed by field office personnel.

3. Providing guidance, approval, and direction for site selection, installation, and operation of all surface-water gaging stations for the field office.

4. Reviewing real-time hydrographs daily on Internet and making or directing staff to make appropriate corrections.

5. Performing technical reviews of surface-water activities carried out by the field office.

6. Managing and directing the processing of all surface-water data in the field office.

7. Providing resolution of any conflicts or disputes related to surface-water activities in the field office.

8. Recommending appropriate training for field office personnel and oversees safety issues for the field office.

The Hydrologic Technicians are responsible for;

1. Conducting work activities in a manner that provides safety for themselves, their fellow employees, and the general public.

2. Collecting hydrologic data in an accurate, unbiased, and representative manner by standard procedures recognized by the USGS and associated earth-science agencies.

3. Following prescribed documentation procedures in order to preserve, protect, and input accurate data into the appropriate databases.

4. Accurately computing, compiling, analyzing, and reporting hydrologic data according to USGS standards and guidelines.

5. Maintaining sampling, measuring, and data-collection equipment in their charge to ensure accurate calibration and operation.

6. Reporting data collected in the appropriate reporting format in an equitable and non-preferential manner to all data users.

The Computer Specialist is responsible for;

1. Developing new software and adapting existing software to meet ARWSC needs.

2. Ensuring that all software systems available for ARWSC users are operating correctly and are updated as required.

3. Training personnel in proper use of software systems and system revisions to ensure data accuracy and processing efficiency.

The Database Administrator is responsible for;

1. Managing databases to ensure data integrity, system security, and user accessibility.

2. Conducting adequate backup and recovery procedures that follow agency guidelines.

3. Maintaining the databases and correcting problems in a timely manner in order to minimize loss of data and user access time.

4. Uploading and downloading data from national database repositories at recommended intervals.

5. Overseeing system security by controlling system access, assigning user identification, and following agency guidelines on computer system security.

The Safety Officer is responsible for;

1. Ensuring that personal safety is the first priority when conducting or planning work activities for the ARWSC.

2. Ensuring that policies and guidelines for work activities follow recommended safety rules and regulations covered in the USGS Safety Manual and related safety publications.

3. Encouraging an attitude of safety awareness in ARWSC employees for activities on and off the job.

4. Assisting and advising supervisory personnel in job safety analysis and job safety training.

5. Ensuring that required safety training is conducted on schedule.

6. Conducting annual safety inspections and assisting personnel in conducting work site inspections when necessary.

The Surface Water Specialist is responsible for;

1. Ensuring that all aspects of this QA plan are understood and followed by ARWSC personnel.

2. Providing guidance on site selection, design, installation, and operations of all surface-water gaging stations in the ARWSC.

3. Performing technical reviews of all surface-water data programs.

4. Reviewing and checking levels

4 5. Providing resolution of conflicts or disputes related to surface-water data analysis activities.

Collection of Stage and Stream flow Data

Many of society's daily activities, including industry, agriculture, energy production, water-way navigation, waste disposal, and recreation, are closely linked to stream flow and water availability; therefore, reliable surface-water data are necessary for planning and resource management. The collection of stage and stream flow data is a primary component in the ongoing operation of stream flow-gaging stations (referred to in the remainder of this report as gaging stations) and other water-resource studies performed by the USGS and the ARWSC.

The objective of operating a gaging station is to obtain a continuous record of stage and discharge at the site (Carter and Davidian, 1968, p. 1). A continuous record of stage is obtained by installing instruments that sense and record water- surface elevation in the stream. Discharge measurements are made at periodic intervals to define or verify the stage- discharge relation and to define the time and magnitude of variations in that relation.

It is the policy of the ARWSC that all personnel involved in the collection of stage and discharge data are informed of and follow the surface-water data-collection policies and procedures established by the WRD.

Gaging Station Installation

Proper installation and maintenance of gaging stations are critical activities for ensuring quality in streamflow-data collection and analysis. Effective site selection, correct design and construction, and regular maintenance of a gage can make the difference between efficient and accurate determination of drainage-basin discharge or time-consuming, poor estimations of flow.

Sites for installation of gaging stations are selected with the intent to meet the purpose of each specific gage. Additionally, sites are selected with the intent of achieving, to the greatest extent possible, ideal hydraulic conditions. Criteria that describe the ideal gaging-station site are listed in Rantz and others (1982, p. 5). These criteria include unchanging natural controls that promote a stable stage-discharge relation, a satisfactory reach for measuring discharge throughout the range of stage, and the means for efficient access to the gage and measuring location. Other aspects of controls considered by ARWSC personnel when planning gage-house installations include those discussed in Kennedy (1984, p. 2).

The individuals responsible for selecting sites for new gaging stations are the Data Chief, Field Office Chief (FOC), Surface Water Specialist, and Project Chief. The process of site selection includes;

1. Discussion with cooperators on the purpose of the gage

2. Analysis of terrain with the use of topographic maps

3. Field reconnaissance

4. File search to determine if discontinued stations or partial record stations existed in the area

5. Determination of rating conditions and gage access.

Responsibilities

The responsibility for ensuring proper documentation of agreements with property owners and approval of site design is the responsibility of the Data Chief, FOC's, Surface Water Specialist, and Safety Officer. Responsibility for construction of gages in a timely, efficient and safe manner is held by the FOC, Lead Hydrologic Technician, and assigned field personnel. Inspection and approval of the completed installation is the responsibility of the Data Chief.

Gaging Station Maintenance

A program of careful inspection and maintenance of gages and gage houses promotes the collection of reliable and accurate data. Allowing the equipment and structures to fall into disrepair can result in unreliable data and safety problems. The following is required ARWSC policy;

1. A visual inspection of gaging station structures is performed by field personnel on every station visit. Any unsafe or potential problems should be brought to the attention of the appropriate FOC immediately, so observed problems can be addressed.

2. To prevent the buildup of mud or the clogging of intakes, stilling wells are pumped annually to prevent mud/silt buildup. More frequent maintenance should be carried out as conditions warrant. Stilling well maintenance must follow WSC safety guidelines and protocols

Other maintenance activities required on a regular basis include;

1. Removing vegetation around gage and in measuring section during annual station maintenance.
2. Repair and maintenance of outside base reference gages as needed
3. Removal of unused/old equipment and associated wiring, fastening materials, and out dated calendars, and other gaging station documentation.
4. Gaging station shelter is kept free of dirt and clutter
5. Rodent problems are addressed immediately through blocking of access points with steel wool, replacement of doors, etc. Poison bait is left in the gage house to kill any rodents that remain.

Responsibilities

It is the responsibility of the Hydrologic Technician assigned to the field trip to ensure that his/her gages and gage houses are kept in good repair. To ensure these responsibilities are carried out, periodic inspections of the gaging station structures are carried out by the supervisors of the Hydrologic Technicians and deficiencies are corrected or reported to the Data Chief.

Gaging Station Equipment Maintenance

Careful inspection and maintenance of gaging station equipment promotes the collection of reliable and accurate data. Allowing the equipment to fall into disrepair can result in unreliable data. It is ARWSC policy that the following equipment checks are required on all gaging station visits;

1. Note condition of battery and replace prior to any potential failure of the battery.
2. Replace nitrogen gas cylinders as needed (never let cylinder go below 200 psi).
3. Replace desiccant on dry air compressors systems before any loss of record due to saturation of desiccant (never let desiccant be less than 1/3 blue).
4. Electronic equipment wiring harnesses are kept in a neat and orderly fashion to reduce the possibility of record loss due to faulty wiring
5. All equipment is kept secured to avoid data loss due to equipment falling/being knocked over.

Responsibilities

It is the responsibility of the Hydrologic Technician assigned to the field trip to ensure that his/her gaging station equipment is kept in good repair. To ensure these responsibilities are carried out,

periodic inspections are carried out by the supervisors of the Hydrologic Technicians and deficiencies are corrected or reported to the Data Chief.

Measurement of Stage

Many types of instruments are available for measuring the water level, or stage, at gaging stations. There are non-recording gages (Rantz and others, 1982, p. 24) and recording gages (Rantz and others, 1982, p. 32). Because the uses for collected stage data cannot be predicted, it is Office of Surface Water policy that surface-water stage records at stream sites be collected with instruments and procedures that provide sufficient accuracy to support computation of discharge from a stage-discharge relation, unless greater accuracy is required (Office of Surface Water memorandum 93.07).

In general, operation of gaging stations for the purpose of determining daily discharge includes the goal of collecting stage data at the accuracy of + or - 0.02 foot or 0.2 percent of effective stage being measured, whichever is less restrictive. An explanation of WRD policy on stage-measurement accuracy as it relates to instrumentation is provided in Office of Surface Water memorandum 93.07 and 96.05.

The type of instrumentation installed at any specific gage house operated by the ARWSC is dependent on the needs of the cooperator, the expected range of stage and availability of equipment. Types of water-level recorders operated by personnel in the ARWSC include Sutron 8200, 8210, Sutron Sat Link (DCPs) and Design Analysis 522+ and JR data-collection platforms. The ARWSC primary pressure sensor is Sutron Accubars though there are also a number of Hydrological Services and Ott bubblers. Design Analysis and Ott radar gages are also used. Stilling wells have either Handar or Sutron shaft encoders.

Responsibilities

The responsibility for determining what type of water-level recorders are operated at each gaging station is held by the Field Office Chief for Little Rock and for Fayetteville. Ensuring that new equipment has been installed correctly is the responsibility of the Hydrologic Technician making the installation. Proper maintenance of gage instrumentation or replacement, if appropriate, of equipment is the responsibility of Hydrologic Technicians who service the gage.

Stage Collection Field Methods

Accurate stage measurement requires not only accurate instrumentation but also proper installation and continual monitoring of all system components to ensure the accuracy does not deteriorate with time (Office of Surface Water memorandum 93.07). To ensure that instruments, located within the gage house, record water levels that accurately represent the water levels of the body of water being investigated, "recorder" and " reference gage" water-level readings are required on each and every station visit. ~~R~~eference gages and associated “recorder” at the ARWSC are;

1. Stilling-well gaging station – Reference gage for recorder is the outside reference gage. The wire weight or staff is the be referred to as the reference gage. Any observed stage differences between the

stilling well and OSS/WWG needs to be noted on field sheet along with potential reasons for the differences.

2. Pressure transducer gaging station - Reference gage for recorder calibration is the outside staff gage (OSS), wire-weight gage (WWG) or reference points (RP). The reference gage used for pressure sensor verification needs to be noted and described on the field sheet.

3. Non-contact radar sensors are used by the ARWSC. The reference gage for the radar is the same that is used for the pressure sensor. The reference gage used for radar verification needs to be noted and described on the field sheet.

Responsibilities

Personnel servicing the gage are responsible for comparing inside and outside readings during each site visit to determine if the outside water level is being represented correctly by the gages. If a deficiency is identified, the personnel servicing the gage are responsible for thoroughly documenting the problem on the field note sheet and either correcting the problem immediately or contacting their immediate supervisor so that corrective actions can be taken at the earliest opportunity.

Ensuring that instrumentation installed at gaging stations is properly serviced and calibrated is the responsibility of the Field Office Chief (FOC). This responsibility is accomplished by regular review of gaging station field notes. When deficiencies are identified, field personnel are counseled on corrective action required. Individuals who have questions related to the calibration and maintenance of water-level recorders should contact their supervisor.

Documentation of Field Observations

Thorough documentation of field observations and data-collection activities performed by field personnel is a necessary component of surface-water data collection and analysis. It is ARWSC policy that all information blocks on the discharge-measurement note, levels note, water quality field note, SWAMI, or gaging station inspection sheets are required to be filled out by field personnel. All entries/data to USGS field forms are made directly and immediately on the form upon their observation. Data/observations are not recorded elsewhere to be transferred at a later date or added based on memory after return to the office. Those headings not applying to the particular measurement/site visit should be notated with a dash so as not to leave any inference that the information was overlooked. Field personnel are responsible for filling out all field sheets or SWAMI completely while at the site. No changes or additions to original data should be made once the field site has been left. To ensure that clear, thorough, and systematic notations are made during field observations, the following specific steps are required;

1. All personnel involved with the discharge measurement/station visit are to be noted with the appropriate initials on the gaging station field note or in SWAMI.

2. Original observations, once written on the field note sheet, are not erased, written over, scribbled out or otherwise made illegible. Original data are corrected by crossing the value out then writing the correct value above, below or next to, the crossed out value. Some examples of original data on a discharge-measurement note sheet include gage readings, arrival and departure times, depth, stationing, velocity readings, meter used, etc

3. Derived data can be erased for the purpose of correction. Examples of derived information on a discharge-measurement note sheet include total discharge on the front sheet, mean gage height, mean velocity, etc.

6. Specific information pertaining to control conditions is written on the field note sheets for the purpose of assisting in the analysis of the surface-water data. The notes should include; a - what the control is, and; b - note the control conditions (i.e., partially blocked, has good fall, or is partially or completely submerged, debris same as last time, etc). Control conditions are to be noted in the field and not added to or modified afterwards, based on memory or photographs. When problems pertaining to artificial controls are encountered by field personnel they should contact their supervisor.

Responsibilities

Field personnel are responsible for filling out all field sheets completely while at the site. No changes or additions to original data should be made once the field site has been left.

A review of field note sheets is required by the FOC as part of surface-water field trip review. Deficiencies found in the content, accuracy, clarity, or thoroughness of field notes are identified and documented. The deficiencies are remedied by providing specific instructions by supervisors to individuals who fail to record notations that meet USGS and ARWSC standards.

Levels

The various gages at a gaging station are set to register the altitude of a water surface above a selected level reference surface called the gage datum. The gage's supporting structures--stilling wells, backings, shelters, bridges, and other structures--tend to settle or rise as a result of earth movement, static or dynamic loads, vibration, or battering by floodwaters and flood-borne debris. Vertical movement of a structure makes the attached gages read too high or too low and, if the errors go undetected, may lead to increased uncertainties in streamflow records. Leveling, a procedure by which surveying instruments are used to determine the differences in altitude between points is used to set the gages and to check them from time to time for vertical movement (Kennedy, 1990, p. 1). Levels are run periodically to all bench marks, reference marks, reference points, and gages at each station for the purpose of determining if any datum changes have occurred (Rantz and others, 1982, p. 545). The level instruments are kept in proper adjustment by peg tests for each period of use. Peg test results are recorded on a "Peg Test of Engineers Levels" form and recorded in a log book for each instrument and noted on each level note. Peg tests are required to be run before each level trip and after periods of extended non-use of the level. ALL levels run in the ARWSC are required to use the form developed by the WSC. The

ARWSC form is the compilation and modification of the three distinct USGS forms, WRD-ID-7, 9-275G, and 9-276.

Levels at gaging stations for the ARWSC will be run at a frequency listed below. Frequency of levels can be changed if sufficient documentation is present to warrant moving a site within the below categories (OSW Technical Memo 90.10). Any change in level frequency from the ARWSC laid out below must be reviewed and approved by the appropriate FOC, in consultation with the Data Chief.

2. Three years - Stable pressure sensor sites, stilling well sites and radar sites.

Reference gages are reset to agree with levels when levels indicates a 0.02-foot or greater vertical change. Resets of less than 0.02 ft should be applied only if there is consistent information of a correction being needed. Level notes are to be checked before the reset is made. When gages are reset, field personnel are required to clearly document the reset on the level note sheet. Levels must include at least one break-set (turn) and must close within **0.003 x n ½** where, n ½ is the square root of the number of turns (i.e. the number of setups). Levels are required to be computed and checked in the field, then rerun if comparison with previous levels shows movement of the base BM/RM or the levels do not close within the accepted error outlined above. Outside water-surface elevations are required and must be referenced to base gage readings by time. Results of the levels are required to be written in the gage house level history.

ARWSC Procedures for leveling of reference gages

WWG - Checkbar and the bottom of the weight, as close to the water surface as safely possible, should be leveled in, and compared to numbers shown on the WWG. Any needed corrections should be applied at that time and noted on the ARWSC level form.

RP's – Top of the RP should be leveled in. A tapedown from the RP should be made to the water surface at that time. Type of equipment used for the tapedown should be noted on the ARWSC level form. The tapedown water surface should be compared to a leveled in water surface for reference purposes only.

Responsibilities

It is the responsibility of the lead field person on the levels run to ensure that the level computations are checked before leaving the site and resetting of any of the base reference gages.

It is the responsibility of the SW Specialist to ensure that all field level notes are reviewed after returning from the field. It also is the responsibility of the SW Specialist to ensure that levels are run correctly, that all level notes are completed correctly, and that levels are run at the appropriate frequency. The level information is then entered in the level-history form by the person responsible for analysis of the record

Discharge Measurements

Direct measurements of discharge are made with any one of a number of methods approved by WRD. The most common discharge measurement method in the ARWSC is the Acoustic Methods. Sontek Flowtrackers (acoustic wading meter) and acoustic doppler current profilers (ADCP) are used in the ARWSC. Methods and standard practices on using the acoustic equipment are located in the hydroacoustic QA plan. Price AA meters should be used as backup to the acoustic meters.

A current-meter and a flow tracker measurement is the summation of the products of the subsection areas of the stream cross section and their respective average velocities (Rantz and others, 1982, p. 80). Procedures used for current-meter and Flowtracker measurements are described in Rantz and others (1982, p. 139), Carter and Davidian (1968, p. 7), and Buchanan and Somers (1969, p. 1). Additional guidelines and procedures to be used with Flowtrackers only, are described in OSW Technical Memorandum 2004.04.

When personnel make measurements of stream discharge, attempts are made to minimize errors. Sources of errors are identified in Sauer and Meyer (1992). These include random errors such as depth errors associated with soft, uneven, or mobile streambeds, or uncertainties in mean velocity associated with vertical-velocity distribution errors and pulsation errors. These errors also include systematic errors, or bias, associated with improperly calibrated equipment or the improper use of such equipment.

Required ARWSC policies related to the measurement of discharge by use of the current-meter method, in accordance with WRD policies, are described as follows;

Depth criteria for meter selection.—ARWSC personnel select the type of current meter to be used for each discharge measurement on the basis of depth criteria presented in Rantz and others (1982, p. 134). Minimum depth criteria is also dependent, in bridge, cableway or boat measurements, on the size of the suspension weight used (Rantz and others, 1982, p. 148). Meters are used with caution when a measurement must be made in conditions outside of the ranges of the method presented in Rantz and others (1982). Any deviations from those criteria are noted and the measurement accuracy is downgraded accordingly.

It is recommended that a change of meters is not made during a measurement in response to the occurrence of two or more subsections in a single measurement cross section that exceed the stated ranges of depth and velocity.

Number of measurement subsections.--The spacing of observation verticals in the measurement section can affect the accuracy of the measurement (Rantz and others, 1982, p. 179). The WRD criteria are that observations of depth and velocity be made at a minimum of 25 to 30 verticals, which are normally necessary so that no more than 5 percent of the total flow is measured in any one vertical. Even under the worst conditions the discharge computed for each vertical should not exceed 10 percent of the total discharge and ideally not exceed more than 5 percent (Rantz and others, 1982, p. 140). Exceptions to this policy are allowed in circumstances where accuracy would be sacrificed if this number of verticals were maintained, such as for measurements during rapidly changing stage (Rantz and others,

1982, p. 174). Fewer verticals than are ideal are sometimes used for very narrow streams (about 12-feet wide when an AA meter is used and about 5 feet wide when a pygmy meter is used). Measurement of discharge is essentially a sampling process, and the accuracy of sampling results typically decreases markedly when the number of samples is less than about 25.

Computation of mean gage height.—ARWSC personnel are required to use procedures for the computation of mean gage height during a discharge measurement that are presented in Rantz and others (1982, p. 170). The mean gage height for any discharge measurement where the change in stage is greater than 0.15 ft needs to be computed using the weighted-mean gage height method described in Rantz and others (1982, p. 172). Mean gage height is one of the coordinates used in describing the stage-discharge relation at a streamflow-gaging site.

Check measurements.--A second discharge measurement (check measurement) is required to be made for the purpose of checking a first discharge measurement when

1. The measurement does not plot on the stage-discharge rating, or on the current shifted rating
2. There is reason to believe the measurement was inaccurate due to such conditions as malfunctioning flowtracker.
3. Measured discharge is greater than or less than any previous measurement
4. Measured discharge is a peak-of-record flow

Corrections for storage.--Corrections for storage applied to discharges measured at a location some distance from the gage are discussed in Rantz and others (1982, p. 177) and in Office of Surface Water memorandum 92.09. These methods should be applied on an as-needed basis in consultation with the FOC or the Data Chief.

Questions.--Personnel who have questions concerning the appropriate procedures for making stage and discharge measurements should address their questions to their supervisor.

Responsibilities

It is the responsibility of the person making the discharge measurement to ensure the guidelines and methods listed above are followed. Any deviation from established procedures and guidelines needs to be clearly documented on the discharge measurement note.

Gaging Station Documents

It is ARWSC policy that certain documents are placed in each gage house for the purpose of keeping an on-site record of observations, equipment maintenance, structural maintenance, and other information helpful to field personnel. Required station documents at each gage house include:

1. Most recent stage-discharge rating
2. Most recent station description listing the following; all gages and reference marks at the site and associated elevations, description of the control, locations of measurement sections, information related to extreme events including the potential for channel storage between the gage and measuring section during flood conditions, and Job Hazard Analysis (JHA)
3. Station log updated by field personnel upon each site visit describing control conditions and listing gage readings, measurement values, observed shift, gage-house maintenance, and equipment maintenance

Responsibilities

It is the responsibility of the Hydrologic Technician assigned to the site to exchange outdated material with updated gage documents as needed/required. When field personnel visit a gage house and identify a need to update one or more of the documents, they should report the deficiency to the supervisor of the Hydrologic Technician responsible for the site. Individuals having questions related to what documents should be kept in a gage house, when the documents should be replaced with newer documents, or appropriate methods of appending logs or plotting measurements should contact the appropriate FOC.

Site Documentation

Thorough documentation of qualitative and quantitative information describing each gaging station is required. This documentation, in the form of a station description and photographs, provides a permanent record of site characteristics, structures, equipment, instrumentation, altitudes, location, and changes in conditions at each site. Information pertaining to where these forms of documentation are maintained is discussed in the section of this report entitled "Office Setting.

Station Descriptions

A station description is prepared for each gaging station and becomes part of the permanent record for each station. Station descriptions are written to include specific types of information in a consistent format (Kennedy, 1983, p. 2) and will include a site specific JHA. It is ARWSC policy that any new station description is written at the time the first year's records are computed. All station descriptions are to be prepared and stored/filed in SIMS (Site Information Management System).

http://tx.cr.usgs.gov/field/sqlsims/StationsRpts.asp

Responsibilities

The responsibility for ensuring that station descriptions are prepared correctly and in a timely manner is held by the FOC. Station descriptions are required to be updated annually during records computation. It is the responsibility of the record checker to ensure that station descriptions are updated as described when the record is checked after each water-year computation is completed.

Photographs

Photographs are made by field personnel for the purpose of documenting gage-house construction, changes in control conditions, or to supplement various forms of written descriptions. Each photograph that becomes part of the station record is identified by writing specific types of information, such as date and discharge, on the back of the photograph with a permanent-ink marker. The ARWSC has specific requirements concerning archiving of photographs. Generally, photographs are filed with unique station ID and in the appropriate water year record in the following directory;

\\lgskedcwfsfiles\surface water information\DARLRK-RawData

Current meter maintenance

Office care of meters

The meters used for backup by ARWSC personnel to measure surface-water discharge are the Price AA current meter and the Price pygmy current meter (although fewer than 5 measurements are made each year using current meters). Required methods followed by ARWSC personnel for inspecting, repairing, and cleaning these meters are described in Smoot and Novak (1968, p. 9), Rantz and others (1982, p. 93), and OSW Technical memorandum 89.07 and 99.06. The ultimate responsibility for the good condition and accuracy of a current meter rests with field person who uses it (Office of Surface Water memorandum 89.07). . All assigned meters potentially used on a field trip must be tested in an office setting (on a level surface, free from effect of wind). The results of the test must be recorded in the spin test log.

The spin test log will contain the meter number, location on the test (office or field), length of spin time in seconds, date of test, initials of person conducting test, and comments such as 'replaced pivot pin', 'meter cleaned and oiled', 'cups straightened'. If the meter fails the spin test, repairs must be made and a subsequent successful test must be conducted. An AA meter in good condition should spin for about 4 minutes, but must spin no less than 1 1/2 minutes. A pygmy meter should spin about 1 1/2 minutes, but no less than 1/2 minute. This log can be found:
\\lgskedcwfsfiles\surface water information\DARLRK-RawData\DARLRK-RawData-2010\AA Current Meter Spin Test Log

Field care and operations

1. Timed field spin tests are required before each measurement and recorded on the field sheet. The meter should be checked to make sure that it spins freely and comes to a smooth stop after the measurement. A comment such as 'OK' or 'free' may be used for the ending spin time on the

measurement. The field spin tests are not required to be compiled/logged in the spin test log with the office spin tests.

Responsibilities

A timed spin test made a few minutes before a measurement does not ensure that the meter will not become damaged or fouled during the measurement. Field personnel are expected to assess apparent changes in velocity and to visually inspect the meter periodically during the measurement to ensure that the meter continues to remain in proper operating condition. These visual inspections of the current meter conditions should be noted on the discharge measurement not, with phrases such as “meter OK” or “meter fouled with grass”, etc.

Acoustic Equipment

Acoustic discharge measuring equipment can be used if available. Care and use of the equipment is described in the Acoustic Quality Assurance plan.

Indirect Measurements

The ARWSC’s policy is to document floods with direct measurements even if this requires use of overtime and/or other personnel not assigned to regular stream gaging trips. Ordinarily Arkansas floods are spring floods and there is ample time to prepare for them. Due to excellent weather radar and communication with NOAA, the WSC normally has adequate time to prepare for rain-storm events. However, a few lead Hydrologic Technicians and some Hydrologists have enough experience or training to make indirect measurements if required.

ARWSC personnel currently trained in indirect measurement methods:

Jaysson Funkhouser, Walter Killion, Dan Wagner

In some situations, especially during floods, it is impossible or impractical to measure peak discharges. There may not be sufficient warning for personnel to reach the site to make a direct measurement, or physical access to the site during the event may not be feasible.

A peak discharge determined by indirect methods is in many situations the best available means of defining the upper portions of the stage-discharge relation at a site. Because extrapolation of a stage-discharge relation, or rating, beyond twice the measured discharge at a gaging station is undesirable and may be unreliable, discharge measurements made by indirect methods during periods of high flows are important forms of data (Rantz and others, 1982, p. 334).

The ARWSC follows data-collection and computation procedures presented in Benson and Dalrymple (1967). That report includes policies and procedures related to site selection, field survey, identification of high-water marks, the selection of roughness coefficients, computations, and the written summary. The ARWSC also follows procedures for measurement of peak discharge by indirect methods presented in Rantz and others (1982, p. 273).

In addition to the general procedures presented in Benson and Dalrymple (1967), the ARWSC follows guidelines presented in other reports that describe specific types of indirect measurements suited to specific types of flow conditions. The slope-area method is described in Barnes (1967) and Dalrymple and Benson (1967). The USGS applies the Manning equation in application of the slope-area method. Procedures for selecting the roughness coefficient are described in Arcement and Schneider (1989). The computer-based tool, program SAC, available to assist in computations of peak discharge with the slope-area method is discussed in Office of Surface Water memorandum 96.03. Procedures for the determination of peak discharge through culverts, based on a classification system which delineates six types of flow, is described in Bodhaine (1982). At sites where open-channel width contractions occur, such as flow through a bridge structure, peak discharge can be measured with methods described in Matthai (1967) and with the Water-Surface Profile Computation model (WSPRO) (Shearman, 1990) or HEC RAS (USACE, 2001). Debris-flow conditions, which are most common in small mountainous basins, are discussed in Office of Surface Water memorandum 92.11.

Determinations of water-surface profiles along a stream channel in association with selected discharges are made when studies are performed that involve delineations of flood plains or when extensions are made to stage-discharge relations at streamflow sites. ARWSC personnel are required to follow the procedures associated with step-backwater methods described in Davidian (1984). The two computer-based tools are available for assisting in the computations of water-surface profiles with step-backwater methods, WSPRO, is discussed in Office of Surface Water memorandum 87.05, and HEC-RAS (USACE, 2001).

General guidelines that are followed by the ARWSC when making indirect measurements include those discussed in Office of Surface Water memorandum 92.10 and in Shearman (1990). Violation of any one of the general guidelines does not necessarily invalidate an indirect measurement (Office of Surface Water memorandum 92.10).

The responsibility for ensuring that indirect measurements are performed correctly is held by the Data Chief. It is required that a review of procedures and documentation be performed and a copy of the measurement summary and reviewer comments are sent to the Regional Surface Water Specialist. If deficiencies are found during the review the Data Chief is responsible to assure that appropriate actions are taken to remedy the situations.

Determining when and where indirect measurements are made in consultation with the Field Office Chief, Surface Water Specialist, and Data Chief. For the ARWSC, it is a general rule that indirect

measurements are made at sites when analysis of the peaks indicates that extension of the rating through excepted means would not produce reasonable results.

It is the responsibility of field personnel to identify and flag high-water marks. Because the quality and clarity of high- water marks are best soon after a flood, personnel traveling in the field are required to have available in their field vehicles marking equipment such as nails, spray paint, survey flagging, etc.

After each indirect measurement is computed, the graphs, field notes and data, plotted profiles, maps, calculations or computer output, and written analysis associated with the measurement are checked by Data Chief or Surface-Water Specialist. Each indirect measurement folder is kept with the station record and sent to the National Archives and Records Administration in Denver.

The responsibility of maintaining the accuracy of the peak-flow data files, including computer database files, lies within the ARWSC (Office of Surface Water memorandum 92.10). It is the responsibility of the Data Chief to ensure that appropriate indirect-measurement results are entered into the peak-flow files. It is the responsibility of the Data Chief to ensure that the peak-flow files are correct. For further discussion on the update and review of the peak-flow files, refer to the "Data-Base Management" section in this QA Plan.

Crest-Stage Gages

Crest-stage gages at recording stations

Crest-stage gages are used as tools throughout the WRD for determining peak stages at otherwise engaged sites, confirming peak stages at selected sites where recording gages are located, confirming peak stages where pressure transducers are used, and determining peak stages along selected stream reaches or other locations, such as upstream and downstream from bridges and culverts.

Flood Conditions

Flood conditions present situations that do not occur on a regular basis. These situations can include difficulties in gaining access to a streamflow gage or measuring site because roads and bridges are flooded, closed, or destroyed. Debris in the streamflow can damage equipment and present dangers to personnel collecting the data. Rapidly changing stage or conditions requiring measurements to be made at locations some distance away from the gage can create problems in associating a gage height to a measured discharge.

The ARWSC maintains a flood plan so that high-priority surface-water data associated with flood conditions are collected correctly and in a timely manner. The flood plan describes responsibilities before, during, and after a flood, informational-reporting procedures, and field-activity priorities. The flood plan serves as a central reference for emergency communications, telephone numbers for key ARWSC personnel and codes for accessing streamflow gages equipped with telemetry.

If other than minor shifts of field responsibility within an office are required within an office area as a result of flooding, the FOC's will bring the situation to the attention of the Data Chief. If the Data Chief determines that use of overtime, additional personnel, or more drastic measures are needed the ARWSC Director or Senior staff will be consulted.

Responsibilities

It is the responsibility of the Data Chief for ensuring that the flood plan includes all appropriate information, including updated information. The flood plan is reviewed annually after the completion of the Annual Data Report. It is the responsibility of the FOC to ensure that individuals that receive a copy of the plan are fully versed on the content of the flood plan. It is the responsibility of the individual hydrotech to be aware of flooding conditions and to alert the FOC or flood coordinator to the occurrence of flooding, if needed.

Procedures during a flood

1. Coordination of flood activities is performed by the Little Rock FOC and the Data Chief (alternate).
2. For personnel that are not already in the field, their first responsibility during flood conditions is to consult with the Flood Coordinator before leaving the office for the field.
3. For personnel that are already in the field, their first responsibility during flood conditions is to immediately call the Flood Coordinator.
4. Personnel who arrive at a gaging station to find that a flood has occurred are responsible for immediately notifying the Flood Coordinator.

The ARWSC field personnel apply methods discussed in Rantz and others (1982, p. 60) for determining peak stage at gaging stations.

The Arkansas Data Program has the responsibility for the planning and execution of the data-collection activities during any flood event.

Localized or routine flood events - data-collection activities will generally be carried out by those individuals who have been assigned to that area where the flooding is occurring. This will be under the supervision of the individual's normal supervisor. It is the responsibility of the field person to keep the supervisor informed of the work that is being done and the magnitude and areal extent of the flooding.

Major flooding events - the control and coordination of work assignments will be the responsibility of the ARWSC Flood Coordinator. In his absence, the ARWSC Director will act as the Flood Coordinator or appoint someone in his place. The Flood Coordinator will be responsible for alerting the ARWSC Director to the extent and seriousness of the flooding and will keep him informed of the plans for covering the flood. The ARWSC Director or their appointee will, in instances of significant or unusual flooding, be responsible for notifying the appropriate WRD personnel in accordance with the WRD Project Alert Program.

ARWSC personnel follow policies and procedures stated in a number of publications and memorandums when collecting surface-water data during floods;

1. Techniques for current-meter measurements of flood flow are presented in Rantz and others (1982, p. 159 to 170).
2. Procedures for identifying high-water marks for indirect discharge measurements are presented in Benson and Dalrymple (1967, p. 11).
3. Adjustments applied to make measured flow hydraulically comparable with recorded gage height when discharge measurements are made a distance from the gaging station are presented in Office of Surface Water memorandum 92.09 and in Buchanan and Somers (1969, p. 54).
4. It is the responsibility of all personnel with questions about particular policies or procedures related to flood activities, or who recognize their need for further training in any aspect of flood-data collection, to address their questions to their supervisors.

Review of ARWSC activities related to floods is the responsibility of the Surface-Water Specialist. This review includes seeing that guidelines and priorities spelled out in the flood plan are followed and that the guidelines appropriately address ARWSC requirements for obtaining flood data in a safe and thorough manner. When deficiencies are identified by the reviewer, deficiencies are remedied by the Data Chief.

Low-Flow Conditions

Streamflow conditions encountered by ARWSC personnel during periods of low flow are typically quite different from those encountered during periods of medium and high flow. Low-flow discharge measurements are made to define or confirm the lower portions of stage-discharge relations for gaging stations, as part of seepage runs to identify channel gains or losses, and to help in the interpretation of other associated data. Additionally, low-flow measurements are made to define the relation between low-flow characteristics in one basin and those of a nearby basin for which more data are available (Office of Surface Water memorandum 85.17).

In many situations, low flows are associated with factors that reduce the accuracy of discharge measurements. These factors include algae growth that impedes the free movement of current-meter buckets and larger percentages of the flow moving in the narrow spaces between cobbles. When natural conditions are in the range considered by the field personnel to be undependable, the cross section is physically improved for measurement by removal of debris or large cobbles, construction of dikes to reduce the amount of nonflowing water, or other such efforts (Buchanan and Somers, 1969, p. 39). After modification of the cross section, the flow is allowed to stabilize before the discharge measurement is initiated.

1. Gage height-of-zero-flow (GZF) measurements are required to be made by field personnel during periods of low flow for rating analysis.

Responsibilities

The individuals responsible for ensuring that ARWSC personnel use appropriate equipment and procedures during periods of low flow is the FOC. Determination that appropriate procedures are used for data-collection activities during low-flow conditions is accomplished when surface-water records are reviewed annually. The FOC's are responsible for providing answers to questions from ARWSC field personnel pertaining to data collection during periods of low flow.

Cold-Weather Conditions

Surface-water activities in the ARWSC include making streamflow-discharge measurements during cold weather conditions. Cold temperatures, wind, snow, and ice can create difficulties in collecting data. These factors also can create dangers to field personnel. The highest priority in collecting streamflow data during winter periods is employee safety.

Processing and Analysis of Stage and Streamflow Data

The computation of streamflow records involves the analysis of field observations and field measurements, the determination of stage-discharge relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. Streamflow records are computed and published for each gaging station annually (Rantz and others, 1982, p. 544).

This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of data associated with the computation of streamflow records. The procedures followed by the ARWSC coincide with those described in Rantz and others (1982) and in Kennedy (1983).

Processing of Real-Time Streamflow Data

A necessary and critical element in maintaining accurate streamflow records on a real-time basis is the need for rating analysis and shift application as soon as practicable after a discharge measurement has been made. The ARWSC's policy is that rating analyses and shift applications will be performed using the following procedures for data disseminated on the ARWSC's public Web page:

http://ar.water.usgs.gov

Under normal conditions, except at critical stations where cooperators needs require special attention, measurements are checked and entered into the database following the field trip. For sites requiring special consideration the field personnel call measurements to the office via cellular phone after completion of each measurement. The FOC's review measurement data called in by field personnel and update the National Water Information System (NWIS) files as appropriate in order to provide accurate data on the Web. During flood operations the measurements also are called in from the field. The

assignment of measurement entry and checking responsibility during floods may be divided if the workload is deemed excessive by the Data Chief.

Web Page Presentation Format

Arkansas real-time data are served from computers located in Little Rock maintained by the ARWSC in conjunction with NATWeb. The NWIS Web software is used to conform to national USGS standards. The Arkansas WSC web page is located at:

http://ar.water.usgs.gov

Review of Real-Time Streamflow Data

Real-time streamflow data that are disseminated on the public Web page must be reviewed at least daily to ensure their quality and to prevent the distribution of erroneous information. The ARWSC utilizes both automated and manual review procedures to meet this objective.

Automated procedures that have been implemented by the ARWSC include the setting of minimum and maximum threshold values for stage and discharge and their rates of change. If exceeded, these settings will block data from being displayed

In addition to the automated procedures, ARWSC policy requires frequent and on-going screening and review of Web data, including at least daily review of hydrographs during normal hours of operation. Critical sites are reviewed on weekends and on holidays as well. The Data Chief determines critical sites. The ARWSC also requires that all Web pages containing real-time streamflow data are reviewed regularly for accuracy and/or missing data.

Responsibilities

Each Hydrologic Technician is responsible for reviewing hydrographs on the web for the stations they are assigned. Unless they are in the field, the Hydrologic Technician will review the hydrographs on a daily basis during the week. For periods where the Technician is out of the office the technician is required to make arrangements with the FOC for web page cleanup.

Error Handling

There are two general types of errors associated with streamflow data that are delivered by the real-time system and disseminated on the Internet. The first are persistent-type problems usually associated with some type of equipment failure whether in data collection or transmission, but could also be related to ice effects. Because of the nature of the problem they generally occur on a continuing basis for more than a single recording interval. The second are the intermittent-type problems, which are often the result of a data transmission error. These often show up as either a zero or an unreasonably large value.

Responsibilities

Errors will be corrected by the Hydrologic Technician assigned the station or by the Field Office Chief.

Data Qualification Statements

WRD Technical Memorandum 95.19 requires that streamflow data made available on the Web should be considered provisional until the formal review process has been completed. To ensure that everyone who accesses data from the Web are aware of this, data qualification statements must be included at key locations with a clickable heading Provisional Data Subject to Revision on all real-time data pages.

Measurements and Field Notes

The gage-height information, discharge information, control conditions, and other field observations written by personnel onto the measurement note sheets and other field note sheets form the basis for records computation for each gaging station. Measurements and field notes that contain original data are required to be stored indefinitely (Hubbard, 1992).

Measurements and other field notes for the water year that is currently being computed are filed in the office record folder kept by the field personnel. Measurements and notes for the previous water years are filed in the folder for that year.

It is ARWSC policy that all measurements by new personnel, flood measurements, and miscellaneous measurements are checked using the computer program or by reviewing the mathematics and other items listed in Kennedy (1983, p. 7).

Responsibilities

The Hydrologic Technician is responsible for checking and computer entry of the measurements.

Continuous Record

Surface-water gage-height data are collected as continuous record (hourly or 15-minute values, for example) in the form of electronic transmissions by satellite, by telephone, or downloaded to field computers. Streamflow records are computed by converting gage-height record to discharge record through application of stage-discharge relations. Ensuring the accuracy of gage-height record is, therefore, a necessary component of ensuring the accuracy of computed discharges.

Records and Computation

Generally, records for each station are assigned to the field person responsible for data collection. The assignments are made by the FOC's. The ARWSC's policy is to work all records on a current basis following each field trip. There are some exceptions to the rule. Records are worked, checked, and reviewed in each office, but record review is exchanged between offices to assure that there is consistency in the review. Data review occurs for a portion of discharge stations through the year.

Responsibilities

The FOC's are responsible for determining and enforcing computation deadlines. The FOC's are responsible for file setup for new gages.

Procedures for Working and Checking Records

Procedures for ensuring the thoroughness, consistency, and accuracy of streamflow records are described in this section of the QA Plan. The goals, procedures, and policies presented in this section are grouped in association with the separate components that are included in the records-computation process.

Gage Height

The accuracy of surface-water discharge records depends on the accuracy of the discharge measurement, the accuracy of rating definition, and the completeness and accuracy of the gage-height record (Office of Surface Water memorandum 93.07). Computation of streamflow records includes ensuring the accuracy of gage-height record by comparisons of gage- height readings made by use of independent reference gages, comparison of inside and outside gages, examination of high- water marks, comparisons of the redundant recordings of peaks and troughs by use of maximum and minimum indicators, examination of data obtained at crest-stage gages, and confirmation or updating of gage datum's by levels.

Records computation includes examination of gage-height record to determine if the record accurately represents the water level of the body of water being monitored. Additionally, it includes identifying periods of time during which inaccuracies have occurred and determining the cause for those inaccuracies. When possible and appropriate, inaccurate gage-height record is corrected. When corrections are not possible, the erroneous gage-height data are removed from the set of data used for streamflow records computation.

ARWSC policy is to delete unit values of erroneous gage heights from the computer data base. The removed erroneous data will be reviewed by use of HYDRA and comparison of computed data with raw data. The "final" primaries will include only good gage height data (gage heights that have been corrected with datum type corrections, obtained from a backup recorder, or effected by backwater to the extent that discharges must be estimated rather than computed). Data replaced by backup recorders will be identified in the station analysis by the person doing the initial record computation.

Levels

Errors in gage-height data caused by vertical changes in the gage or gage-supporting structure can be measured by running levels. Gages can be reset or gage readings can be adjusted by applying corrections based on levels (Kennedy, 1983, p. 6).

Procedures for computing records for each station include checking levels, ensuring that the level information was listed in the historical levels summary and ensuring that information was applied appropriately as datum corrections. The individual computing the record is required to check field notes for indications that the gages were reset correctly by field personnel and makes appropriate adjustments to the gage-height record by applying datum corrections. The checker makes appropriate comments on the record review form, if proper procedures have not been followed.

Rating

The development of the stage-discharge relation, also called the rating, is one of the principal tasks in computing discharge record. The rating is usually the relation between gage height and discharge (simple rating). Ratings for some special sites involve additional factors such as rate of change in stage or fall in slope reach (complex ratings) (Kennedy, 1983, p. 14).

ARWSC personnel follow procedures for the development, modification, and application of ratings that are described in Kennedy (1984). ARWSC personnel also follow guidelines pertaining to rating and records computation that are presented in Kennedy (1983, p. 14) and in Rantz and others (1982, Chap. 10-14 and p. 549). ARWSC personnel are required to plot the last 10 years of discharge measurements on all ratings, especially when a new rating is being developed. GRSAT should be used in rating development.

For each gaging station, the most recent digital rating table can be obtained from NWIS, or the station file. A graphical plot of the most recent rating can be obtained from the station file folders or printed from NWIS.

New ratings by less experienced personnel must be discussed and reviewed with the FOC, senior hydrographers, or with the Data Chief before development starts. All new ratings must be approved by the FOC or data Chief, or it will be returned for reworking. Judgment must be used for determining the appropriate high-flow measurements to show on the graph. New rating numbers must be used if any values on the new rating differ from the old rating. Extensions do not require new numbers as long as no changes are made to the existing rating values. The ARWSC uses GRSAT to develop all new ratings and extensions. This practice has been in place for the last two years.

Responsibilities

It is the responsibility of the person drawing the rating to get approval from the FOC, senior hydrgraphers, or Data Chief prior to use.

Gage-Height Corrections

A correction applied to gage-height readings to compensate for differences between the recording gage and the base gage is called a "gage-height correction" (Rantz and others, 1982, p. 563. Gage-height corrections are applied so that the recorded data are made to agree with base reference gage. These corrections are applied when the difference between the recording gage and the base gage is equal to or greater than 0.02 ft.

Datum Corrections

A correction applied to gage-height readings to compensate for the effect of settlement or uplift of the base gage usually is measured by levels and is called a "datum correction" (Kennedy, 1983, p. 9). Datum corrections are applied to gage-height record in terms of magnitude (in feet) and in terms of when the datum change occurred. In the absence of any evidence indicating exactly when the change occurred, the change is assumed to have occurred gradually from the time the previous levels were run, and the correction is prorated with time (Rantz and others, 1982, p. 545) unless there is reason to believe the correction is event based. Datum corrections are applied when the magnitude of the vertical change is equal to or greater than 0.015 foot. All datum corrections will be applied in Table 2 of the ADAPS PR 3.

Shifts

A correction applied to the stage-discharge relation, or rating, to compensate for variations in the rating is called a shift. Shifts reflect the fact that stage-discharge relations are not permanent but vary from time to time, either gradually or abruptly, because of changes in the physical features that form the control at the gaging station (Rantz and others, 1982, p. 344). Shifts can be applied to vary in magnitude with time and with stage (Kennedy, 1983, p. 35). Stage shifts rather than time shifts are encouraged. Unless there is a well documented reason, the shift for the upper data pair on the V-shift diagram should be "zero". All stage shifts are applied in ADAPS PR 6. The use of GRSAT in shift development is starting to be used in the WSC.

Hydrographs

A discharge hydrograph is a plot of daily mean discharges versus time. The date is aligned with the horizontal axis and the discharge is aligned with the logarithmic vertical axis. In the process of computing station records, this hydrograph is a useful tool in identifying periods of erroneous information, such as incorrect shifts or datum corrections. Additionally, hydrographs are helpful when estimating discharges for periods of undefined stage-discharge relation, such as during backwater or ice conditions, and in estimating discharges for periods of missing record.

Information placed on the hydrograph for each station includes the station name, station number, water year, plot of daily mean discharge data, and plots of measurements. Hydrographic comparison should be made with other gages either upstream or downstream on the same river or with adjacent basins.

Any questions regarding discharge estimates should be referred to FOC's, senior hydrographers, or the Data Chief. Hydrographs can be view using HYDRA, GRSAT or by using PLOTWAT.

Station Analysis

A complete analysis of data collected, procedures used in processing the data, and the logic upon which the computations were based is documented for each period of record for each station to provide a basis for review and to serve as a reference if questions arise about the records at some future date (Rantz and others, 1982, p. 580). Topics discussed in detail in the station analysis include equipment, gage-height record, datum corrections, gage-height corrections, rating, discharge, and remarks (Rantz and others, 1982, p. 580). The station analysis is written by the individual who prepares the initial computation for the period of record. The station analysis form is located in RMS;

http://tx.cr.usgs.gov/field/sqlsims/start.asp?office_id=2&district_cd=05

Daily Values Table

With few exceptions, for each discharge gaging station operated by the ARWSC a mean daily discharge value and a mean daily gage-height value, are determined and stored for each day. The daily values table generated by use of the records-computation software represents what daily values are stored for each day of the water year. The daily values table represents the final values of computed discharge. All daily values changed manually must be individually checked by the checker. Minor changes in daily values, such as recomputed shifts or modified ice estimates may be made by the checker and noted on the ARWSC check form. However, records requiring significant revisions may either be redone and returned to the original computer for checking or just returned for reworking.

Manuscript and Annual Report

When records computation for the water year has been completed and the data collected and analyzed by ARWSC personnel have been determined to be correct and finalized, the surface-water data for that water year are published along with other data in the ARWSC's annual data report. The annual data report is part of the series titled "Water-resources data for the United States." Information presented in the annual data report includes daily discharge and gage-height values during the year, extremes for the year and period of record, and various statistics. Additionally, manuscript station descriptions are presented in the annual data report. Information contained in the manuscript includes physical descriptions of the gage and basin, history of the station and data, and statements of cooperation. This manuscript information is stored and modified in SIMS (Station Information Management System), and can be found at:

http://tx.cr.usgs.gov/field/sqlsims/StationsRpts.asp

In preparing the annual data report for publication, the ARWSC follows the guidelines presented in the report, "WRD Data Reports Preparation Guide," by Charles E. Novak (1985). A copy of the previous

year's manuscript is updated by the person working the record, checked by the reviewer and provided to the Publications Unit.

Records completion progress is tracked in the RMS (Records Management System) portion of SIMS (Station Information Management System):

http://tx.cr.usgs.gov/field/sqlsims/StationsRpts.asp

Check of records

After streamflow records for each station have been computed all records for the ARWSC's gaging stations are checked by the Data Chief, FOC's and Senior Hydrologic Technicians. The goal of the check is to ensure that proper methods were applied throughout the process of obtaining the surface-water data and computing the record. Check sheets listing deficiencies and/or pointing out good work are completed in RMS for each record. The individual responsible for computing the record may dispute any changes upon receipt of the RMS email indicating that the record has been checked. It is at the checkers discretion whether they make required updates or return the record to the original analyst. Disputes between analysts and checker are resolved by the FOC's or the Data Chief.

Review of records

After streamflow records for each station have been computed and checked they all will be reviewed by the Senior Hydrographers or the FOC. Records will be reviewed for consistency, completeness, accuracy, and for following of USGS and ARWSC policies. Rejected records will be returned to the individual computing the record. Deficiencies in the record also will be discussed with the checker. Following an acceptable review, the reviewer will set the record flags to "final" and send the manuscript to the Publications Unit for updating in SIMS.

Responsibilities

Responsibility for computation of annual peaks at stage gages is the responsibility of the Hydrologic Technician assigned to the gage. Checking and reviewing of the stage gage computations is performed by the senior hydrographers and the FOC. Advice from other Hydrologists is available if necessary.

Responsibility for overseeing update of the peak-flow file promptly after peak data have been finalized is held by the Data Chief. A current listing of annual peaks is-available online and in the database.

Office Setting

Maintaining surface-water data and related information in a systematic and organized manner increases the efficiency and effectiveness of data-analysis and data-dissemination efforts. Good organization of files reduces the likelihood of misplaced information; misplaced data and field notes can lead to analyses based on inadequate information, with a possible decrease in the quality of analytical results.

This section of the QA Plan includes descriptions of how station folders, reference maps, levels documentation, and other information related to surface-water data are organized and maintained. Additionally, this section provides an overview of how work activities are designated to be carried out within the office setting.

File Folders for Surface-Water Stations

This section of the QA Plan describes the location and makeup of hard-copy files associated with surface-water data. Information pertaining to files maintained in computer storage can be found in the "Data-Base Management" section of this report.

For each gaging station, a separate set of file folders is maintained. These folders are identified by station number (Little Rock) or alphabetical (Fayetteville) by water year. Each station also has a permanent folder kept in the same location as the water-year folder. Extraneous items are removed from the current water year files after records are determined to be finalized each year.

1. Water-Year folders - WY folders must contain; a - level history summary sheet; b - station description; c - rating curve, and; d - rating plot including the past 10 years of measurements and the most recently superseded rating.

2. Analysis Period Folders – analysis period folders should contain, but are not limited to, such items as recent measurement field note sheets, discharge measurements, discharge summary sheet, the most current station analysis, shift and datum summary tables. This folder should contain any documents related to the working up of the analysis period.

3. Permanent folders - Permanent folders should contain gaging station photographs, and any station documents unrelated to the water year record computation.

<u>Responsibilities</u>

It is the responsibility of each field office to maintain the files in proper order. Only field folders should be removed from the office. Original data such as discharge measurements or level notes should not be removed from the office.

Field Folders

Field folders contain such items as station description, JHA, bridge safety plan, map on how to get to the station, copy of rating table and rating curve, discharge measurement summary sheet, and any other information necessary to maintain the gaging station (such as DCP programming information, etc.). The field folders are kept by and maintained by the technician responsible for each site.

Gage House Folders

Gage House Folders contain such items as site visit log sheet, station description, JHA, bridge safety plan, copy of rating table and/or rating curve, discharge measurement summary sheet, and any other information necessary to maintain the gaging station (such as DCP programming information, etc.).

Levels

Level notes from the current year are kept with the current record folder. Information from the level notes is entered into the level history. A copy of the level history is kept in the current water-year folder and the permanent file folder.

Station Descriptions

Copies of the surface-water station descriptions are kept in the water year file folder. These folders are organized in downstream order in Little Rock and alphabetical order in Fayetteville. The station descriptions are updated annually when the records are computed. The station description can also be found in SIMS (Station Information Management System):

http://tx.cr.usgs.gov/field/sqlsims/StationsRpts.asp

Archiving

All WRD personnel are directed to safeguard all original field records containing geologic and hydrogeologic measurements and observations. Selected material not maintained in field offices are placed in archival storage. Detailed information on what records have been removed to archival centers are retained in the ARWSC office. The types of original data that should be archived include, but are not limited to, recorder charts and tapes, original data and edited data, observer's notes and readings, station descriptions, analyses, and other supporting information (Water Resources Division memorandum 92.59 and Hubbard, 1992, p. 12). At this time there is an agreement between WRD and the Federal Records Centers (FRC) of the National Archives and Records Administration to archive original-data records (memorandum from the Chief, Branch of Operational Support, May 7, 1993).

Surface-water information is sent to the FRC from the ARWSC about every 2-3 years or as needed after the records have been scanned. The Data Clerk is responsible for deciding what information is sent to the FRC, for ensuring that the information is properly packed and logged, and for ascertaining that the information is received by the FRC. Records of exactly what has been archived are maintained by the Data Clerk. Personnel who have questions concerning archiving procedures should address their questions to the Data Clerk. Personnel who receive requests for information that require accessing archived records should refer the request to the Data Clerk.

The raw computer copy of the measurements, data dumps, flowtracker checks, and spin test logs are located in the directory below. They are organized according to water year and station number.

\\lgskedcwfsfiles\surface water information\DARLRK-RawData

Communication of New Methods and Current Procedures

The Data Program holds or bi-annual program meetings. Generally, a half-day to a day is committed to safety training; one or two days are used for technical training, such as instrumentation trouble-shooting; and a half day is the Data Program meeting on policy, procedures, and program.

The FOC in Fayetteville meets monthly for a short time with the Fayetteville staff for discussion of the office operations. Little Rock personnel meet on a less frequent basis on an "as needed" basis. All WRD memos are delivered to all employees via email and discussed at the meetings described above.

Quarterly ARWSC meetings are held in the Little Rock office with Fayetteville linked via telephone. Also, quarterly visits are made to the Fayetteville office by the Data Chief.

Collection of Sediment Data

Surface-water activities in the ARWSC include the collection, and publication of sediment data. Periodic suspended sediment samples are the only samples collected on a regular basis. There are no daily or observer sites. The ARWSC operates in adherence to policies related to sediment set forth by the Office of Surface Water.

Responsibility for the sediment discipline was transferred from the Office of Water Quality to the Office of Surface Water in 1985 (Office of Surface Water memorandum 92.08). The policies and procedures related to sediment followed by the ARWSC are described in selected WRD publications and in memorandums issued by the Office of Surface Water, the Office of Water Quality, and the WRD. Techniques adopted by the USGS and followed by this ARWSC are presented in Knott and others (1992). The ARWSC also follows procedures presented in three publications for the series "Techniques of Water-Resources Investigations of the U.S. Geological Survey" (TWRI):

Book 3, Chapter C1--"Fluvial Sediment Concepts" by H.P. Guy (1970),
Book 3, Chapter C2--"Field Methods for Measurement of Fluvial Sediment" by H.P. Guy and V.W. Norman (1970),
Book 3, Chapter C3--"Computation of Fluvial-Sediment Discharge" by George Porterfield (1972).

Although no additional TWRI chapters have been written to supersede the above-mentioned reports, Open-File Report 86-531 "Field Methods for Measurement of Fluvial Sediment" by T.K. Edwards and G.D. Glysson (1988) essentially replaces Book 3, Chapter C2 (Water Resources Division memorandum 71.73, Office of Surface Water memorandum 88.17, and Office of Surface Water memorandum 93.01).

A summary of memorandums issued since 1971 related to sediment and sediment transport is provided in Office of Surface Water memorandum 92.08. A summary of documentation that describes

instrumentation and field methods for collecting sediment data is provided in Office of Surface Water memorandum 93.01.

Sampling Procedures

ARWSC personnel collect suspended-sediment data by using sampling methods that include either the Equal Discharge Increment (EDI) method or the Equal Width Increment (EWI) method. Automatic pumping-type samplers are not used.

Field methods for sediment sampling are documented in Office of Surface Water memorandum 93.01. Water samples obtained for the analysis of sediment concentration and particle size are not composited (Office of Surface Water memorandum 93.01 and Office of Water Quality memorandum 76.17). For samples that are split, the cone splitter is used (Office of Water Quality memorandum 80.17).

The individual in the ARWSC responsible for scheduling sediment-collection activities and for ensuring that ARWSC personnel use correct procedures to collect sediment data is the FOC. The FOC establishes whether or not correct procedures are being used by performing a site trip with each person and by discussing procedures and problems. Answers to questions from ARWSC personnel concerning sediment-sampling techniques are provided by the Data Chief or the Water Quality Specialist.

Field Notes

ARWSC personnel are required to fill out note sheets each time a site is visited for the purpose of sediment sampling. The field staff must complete the note sheet in its entirety before leaving the site. All entries/data to USGS field forms are made directly and immediately on the form upon their observation. Data/observations are not recorded elsewhere to be transferred at a later date or added based on memory after return to the office. Those headings not applying to the particular measurement/site visit should be notated with a dash so as not to leave any inference that the information was overlooked. Original observations, once written on the note sheet, are not erased, written over, scribbled out or otherwise made illegible. Original data are corrected by crossing the value out then writing the correct value above, below or next to the crossed out value. The goal of placing information on the field note sheet is to describe the equipment and methods used during the site visit as well as to describe relevant conditions or changes (Office of Surface Water memorandum 91.15). For each site visit, information included on the note sheet includes, at minimum, station name, site identification, initial of all attending field personnel, date, time, sampling equipment and sampling method.

Upon completion of each field trip, field notes are placed in the water-quality (QW) data entry bin. The data entry person checks field notes and enters the data into QW NWIS.

Equipment

Care and maintenance of the sediment-data-collection equipment is the responsibility of the Hydrologic Technician the equipment is assigned. Parts replacement and repair of damaged equipment is the responsibility of the assigned Hydrologic Technician, or the person who broke the equipment. It is the responsibility of the FOC, in consultation with the Water Quality Specialist, to ensure that appropriate equipment is used at all sampling sites. Sampling equipment is selected based on the constituents that are being investigated, the type of analyses that are to be performed, and site conditions, especially velocity and maximum depth of water. The ARWSC follows equipment-design criteria and guidelines referenced in Office of Surface Water memorandum 93.01.

Sample Handling and Storage

The quality of sediment data provided by a sediment laboratory is affected by the quality of the samples received from the field (Knott and others, 1992, p. 2). ARWSC personnel are required to prepare sample labels, analysis instructions, and sample documentation according to guidelines presented in Knott and others (1992).

Prior to when sample containers are obtained for use on field trips, they are sealed with lids and stored in wire mesh crates or cardboard boxes in the Little Rock or Fayetteville warehouse. During field trips and prior to use, sample containers are stored in the field vehicle. Once the containers have been filled with sediment samples, the samples are stored for the remainder of the field trip in the field vehicles. After the field trip, samples are loaded into shipping containers, the analytical requests are completed, and the samples are mailed first class to the Sediment laboratory. If weather conditions are below 0 degrees F, the shipment is detained until the weather warms.

High-Flow conditions

High-flow conditions at most streams, unless the streams are subject to the effects of backwater, are associated with high-energy conditions. The sediment load and particle sizes associated with high flows are significant factors in sediment studies performed by the ARWSC. It is the FOC's responsibility to ensure that field personnel are aware of their responsibilities in obtaining sediment samples at appropriate sites during high-flow conditions. The individual responsible for ensuring that the proper sampling equipment and methods are used during high-flow conditions is the technician responsible for the site. The Project Chief or FOC will check to ensure that the proper samples are collected. The Water-Quality Specialist is responsible for providing answers to ARWSC personnel who have questions concerning high-flow sampling equipment or sampling procedures.

Site Documentation

The ARWSC currently does not operate any daily sediment stations. Sites with periodic suspended-sediment are located at surface-water stations and are identified on the water-quality sample summary sheets provided to field personnel by the Water-Quality Specialist.

Processing and Analysis of Sediment Data

Sediment and associated streamflow data are compiled to produce sediment records for specific sites. Data processing of periodic measurements consists of four steps: tabulation, evaluation, editing, and verification (Office of Surface Water memorandum 91.15). The ARWSC follows the considerations and guidelines presented in Porterfield (1972), Guy (1969), and Office of Surface Water memorandum 91.15 in carrying out these four steps.

When sediment records are produced, the responsibility for ensuring that appropriate procedures are correctly applied in processing sediment data is held by the person working the record and by the FOC who will check the record. Finally, The Water-Quality Specialist will review the computed record to ensure proper methods and associated guidelines are used/followed. During the time the sediment data are being processed for the year, field notes and work sheets for each site are maintained in the current record folder for sediment. After the record has been completed, field notes and work sheets are maintained in the backfile folder for the specific water year.

Sediment Laboratory

A sediment laboratory is not operated in the ARWSC.

Sediment Analysis Results

Suspended sediment concentrations are published with the water-quality data in the annual report.

Sediment Data Storage

Data are stored in the QW file in NWIS.

Database Management

Personnel responsible for surface-water data collection have authorization for updating NWIS files. However, only the Data Chief and FOC's have authorization to set the "provisional/final" flags. The Surface-Water Database Administrator maintains the peak-flow file, updating the data at the conclusion of the annual data report period.

Publication of Surface-Water Data

The act of Congress (Organic Act) that created the U.S. Geological Survey in 1879 established the Survey's obligation to make public the results of its investigations and research and to perform, on a continuing, systematic, and scientific basis, the investigation of the geologic structure, mineral resources and products of the National domain (U.S. Geological Survey, 1986, p. 4). Fulfilling this obligation includes the publication of surface-water data and the interpretive information derived from the analyses of surface-water data.

Publication Policy

The USGS and WRD have created specific policies pertaining to publication of data and interpretation of those data. All WRD personnel, including those of the ARWSC, are required to abide by those policies. A brief summary of goals, procedures, and policies are presented in U.S. Geological Survey (1986, p. 4-37).

All information obtained through investigations and observations by the staff of the USGS or by its contractors must be held confidential and not be disclosed to others until the information is made available to all, impartially and simultaneously, through Director-approved formal publication or other means of public release, except to the extent that such release is mandated by law (U.S. Geological Survey, 1986, p. 14). With the approval of the Director, hydrologic measurements resulting from observations and laboratory analyses, after they have been reviewed for accuracy by designated WRD personnel, have been excluded from the requirements to hold unpublished information confidential (U.S. Geological Survey, 1986, p. 15).

All interpretive writings in which the USGS has a proprietary interest, including abstracts, letters to the editor, and all writings that show the author's title and USGS affiliation must be approved by the Director before release for publication. The objectives of the Director's review are to final-check the technical quality of the writing and to make certain that it meets USGS publication standards and is consistent with policies of the USGS and Department of the Interior. Director's approval ensures that (1) each publication or writing is impartial and objective, (2) has conclusions that do not compromise the USGS official position, (3) does not take an unwarranted advocacy position, and (4) does not criticize or compete with other governmental agencies or the private sector (U.S Geological Survey, 1991, p. 10).

Types of Publications

Various types of book publications released by the USGS are available in which surface-water data and data analyses are presented. Publications of the formal series include the Water-Supply Paper, the Professional Paper, the Bulletin, the Circular, the Techniques of Water-Resources Investigations, Special Reports, and Selected Papers in the Hydrologic Sciences (U.S. Geological Survey, 1986, p. 42). Publications in the informal series include the Scientific Investigations Report, the Open-File Report, and the Administrative Report (U.S. Geological Survey, 1986, p. 52). Included in the Open-File Report series are data reports. Surface-water data collected by the ARWSC are published each year in a hydrologic data report that belongs to the annual series titled "U.S. Geological Survey Water-Data Reports." Factors considered by the ARWSC when deciding which form of publication should be utilized in presenting various types of information are presented in Green (1991, p. 14).

Review Process

Procedures for publication and requirements for manuscript review by WRD are summarized in U.S. Geological Survey (1991, p.36-41). The ARWSC fulfills those requirements for review and approval of reports prior to printing and distribution. All reports written by USGS scientists in connection with their official duties must be approved by the originating Division and the Director. At least two technical

reviews of each report are required by WRD (U.S. Geological Survey, 1991, p. 36). Competent and thorough editorial and technical review is the most certain way to improve and assure the high quality of the final report (Moore and others, 1990, p. 24). Principles of editorial review and responsibilities of reviewers and authors are presented in Moore and others (1990, p. 24-49). Open-File Reports are not required to receive editorial review, but are reviewed for policy and reproducibility (U.S. Geological Survey, 1991, p. 36).

Once the reviewer has completed a record and furnished the "final" daily value table and manuscript a final copy is prepared. When the report is complete the Data Chief and other senior data personnel divide up the report and do a final review for consistency and to catch gross errors (such as wrong manuscript attached to the daily value table).

Safety

Performing work activities in a manner that ensures the safety of personnel and others is of the highest priority for the USGS and the ARWSC. Beyond the obvious negative impact unsafe conditions can have on personnel, such as accidents and personal injuries, they also can have a direct effect on the quality of surface-water data and data analysis. For example, errors may be made when an individual's attention to detail is compromised when dangerous conditions create distractions. So that personnel are aware of, and follow, established procedures and policies that promote all aspects of safety, the ARWSC communicates information and directives related to safety to all personnel by in-house classes, memorandums, showing videotapes and discussing safety at quarterly section meetings. Specific policies and procedures related to safety can be found in the ARWSC Safety Manual or on the Water Resources Home Page for safety:

It is the responsibility of each employee to read the safety memorandum provided and follow all required safety procedures (such as wearing PFD's). The Collateral Duty Safety Officer's (CDSO) duties, in addition to those outlined below, include maintaining records of required safety training and informing ARWSC Management of training needs.

Expectations and responsibilities of the CDSO

The CDSO is not expected to;

- Fix potential safety problems.
- Resolve any potential safety violations by WSC staff.
- Correct staff that have violated WSC safety procedures.

The CDSO responsibility is to alert management immediately so corrective actions can be taken.

The CDSO is expected to;

- keep management informed of any changes/updates in USGS safety procedures and protocols.

- maintain safety files and update required safety documents, as needed and in a timely manner.
- listen to, and document any safety concerns brought to by staff and bring these concerns to the attention of management in a timely manner.
- help promote a safety oriented culture in the WSC

Personnel who have questions or concerns pertaining to safety, or who have suggestions for improving some aspects of safety, direct those questions, concerns, and suggestions to their supervisor or the ARWSC Safety Officer.

Training

Each employee is asked to annually update their training needs. These needs are discussed during the performance interviews with their supervisors. Upon supervisor approval the training requests are incorporated into the ARWSC Training Plan which is used as a database for nominations by the ARWSC Training Officer.

Summary

Information included in the ARWSC Surface-Water QA Plan documents the policies and procedures of the ARWSC that ensure high quality in the collection, processing, storage, analysis, and publication of surface-water data. Specific types of surface-water data discussed in this report include stage, streamflow, sediment, and basin characteristics. The roles and responsibilities of ARWSC personnel for carrying out these policies and procedures are presented, as are issues related to management of the computer database and issues related to employee safety and training.

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Bodhaine, G.L., 1982, Measurement of peak discharge at culverts by indirect methods: U.S. Geological Survey Techniques of Water- Resources Investigations, book 3, chap. A3, 60 p.
Buchanan, T.J., and Somers, W.P., 1969, Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water- Resources Investigations, book 3, chap. A8, 65 p.

Carter, R.W., and Davidian, Jacob, 1968, General procedures for gaging streams: U.S. Geological Survey Techniques of Water- Resources Investigations, book 3, chap. A6, 13 p.
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____ 1984, Discharge ratings at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A10, 59 p.
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U.S. Geological Survey, 1991, Suggestions to authors of the reports of the United States Geological Survey, 7th ed., revised and edited by W.R. Hansen: U.S. Geological Survey special book publication, 289 p.

Appendix 1.

Water Resources Division and Office of Surface Water Memorandums Cited
The following memorandums were cited in the report.

Office of Surface Water memorandum 05.07
Office of Surface Water memorandum 04.04
Office of Surface Water memorandum 03.07
Office of Surface Water memorandum 99.06
Office of Surface Water memorandum 93.12
Office of Surface Water memorandum 93.12
Office of Surface Water memorandum 93.12
Office of Surface Water memorandum 93.07
Office of Surface Water memorandum 93.01
Office of Surface Water memorandum 92.11
Office of Surface Water memorandum 92.10
Office of Surface Water memorandum 92.09
Office of Surface Water memorandum 92.08
Office of Surface Water memorandum 92.04
Office of Surface Water memorandum 91.15
Office of Surface Water memorandum 90.10
Office of Surface Water memorandum 90.01
Office of Surface Water memorandum 89.08
Office of Surface Water memorandum 89.07
Office of Surface Water memorandum 88.18
Office of Surface Water memorandum 88.17
Office of Surface Water memorandum 88.07
Office of Surface Water memorandum 85.17
Water Resources Division memorandum 92.59
Water Resources Division memorandum 77.83
Water Resources Division memorandum 71.73
Office of Water Information Technical Memorandum No. 2002.10
Water Resources Division technical memorandum 95.19
Water Resources Division technical memorandum 97.17
Office of Water Quality memorandum 80.17
Office of Water Quality memorandum 76.17

Memorandum from the Chief, Branch of Operational Support, May 7, 1993.

All cited WRD memorandums can be found at the following URL:

http://water.usgs.gov/admin/memo/